Comparison of angular methods III

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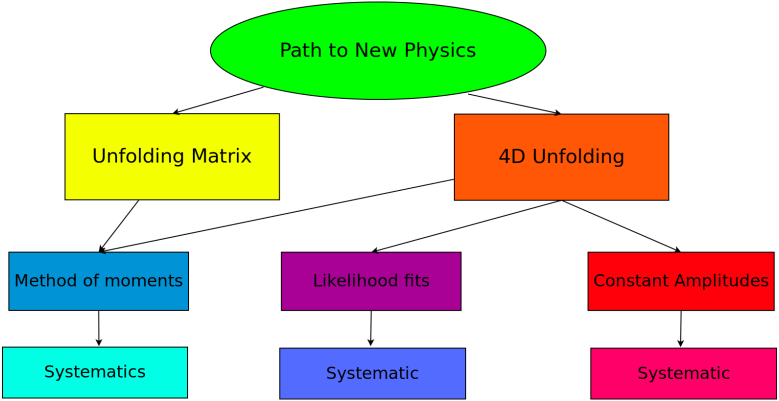
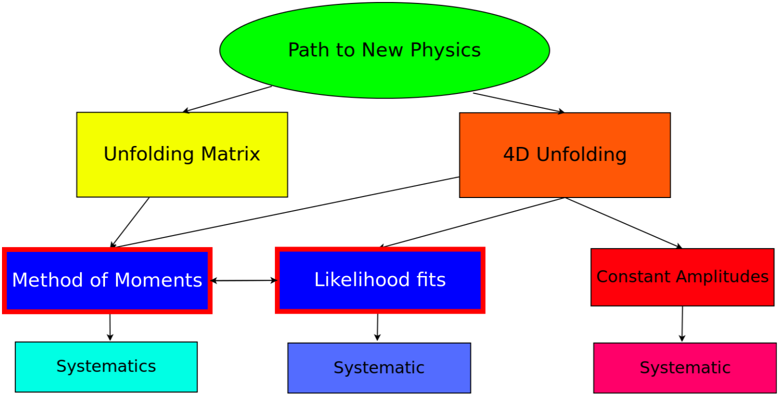
Quo vadis $\mathbf{B^0 \to K^*\mu\mu}$?

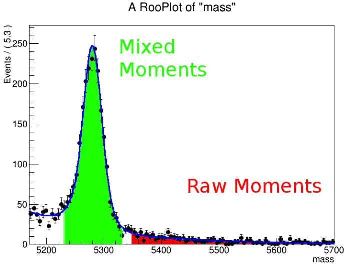


Quo vadis $B^0 \to K^* \mu\mu$?



How to use Moments

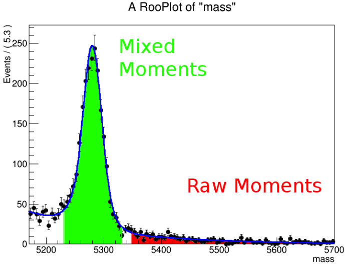
1. Method of moments still uses fits.
2. Extended likelihood fit is used to extract number of signal and background events.
3. Calculate raw moments in bck window $masss > 5350$ and signal window $mass \in [5230, 5330]$
4. Use a simple weighted average:



$$M_{mix} = \frac{n_{sig} M_{sig} + n_{bkg} M_{bkg}}{n_{sig} + n_{bkg}} \qquad (1)$$

How to use Moments

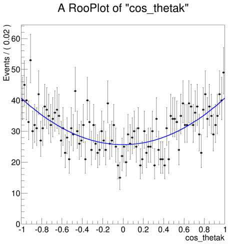
1. Method of moments still uses fits.
2. Extended likelihood fit is used to extract number of signal and background events.
3. Calculate raw moments in bck window $masss > 5350$ and signal window $mass \in [5230, 5330]$
4. Extract signal moments:

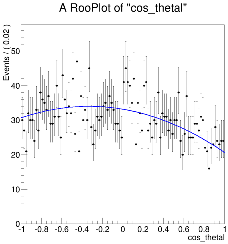


$$M_{sig} = \frac{(n_{sig} + n_{bkg})M_{mix}}{n_{sig}} - \frac{n_{bkg} m_{bkg}}{n_{sig}} \quad (1)$$

How to use fits 1/2

- Assuming we can decouple in the PDF the angular and mass part: $PDF(\theta_l, \theta_k, \phi, m) = PDF_1(\theta_l, \theta_k, \phi) \times PDF_2(m)$
- PDF_1 is our PDF defined in previous presentation.
- PDF_2 is double CB as defined in Christoph toy creation.
- For background we assume 2nd order Chebyshev polynomials($PDF_{1,bck}$)
- And single exponential for bkg part($PDF_{2,bck}$)





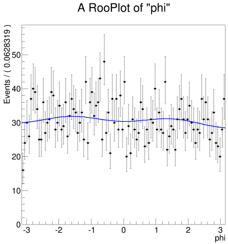
How to use fits 2/2

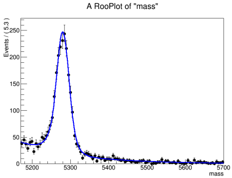
What is left free in the fit:

- λ for exponent.
- F_l, S_x for angular distribution.
- Relative normalization of signal and bkg.

Other remarks:

1. I am using good old Roofit, not custom developed fitter.
2. No s-wave in the fits, or systematics include in this study.
3. individual toys are now provided by Christoph, so one can compare 1 : 1.





Small things

General remark:

- All pull plots/fits are available: LINK
- User: lhcb, password: 2924.

MM results $1GeV$ binning, Mean bias

Q^2	F_l	S_3	S_4	S_5	S_6
0	$-0.431 \pm 0.0184(-23.4)$	$0.00218 \pm 0.0186(0.118)$	$0.0389 \pm 0.0183(2.13)$	$0.0104 \pm 0.0183(0.564)$	$0.0357 \pm 0.0183(1.96)$
1	$-0.029 \pm 0.0188(-1.56)$	$0.0247 \pm 0.0187(1.32)$	$0.016 \pm 0.0184(0.872)$	$-0.0125 \pm 0.0191(-0.657)$	$-0.00833 \pm 0.0186(-0.449)$
2	$0.0090 \pm 0.0181(0.501)$	$-0.0226 \pm 0.0186(-1.21)$	$-0.00623 \pm 0.018(-0.347)$	$-0.0235 \pm 0.018(-1.3)$	$-0.0201 \pm 0.0183(-1.1)$
3	$-0.046 \pm 0.0183(-2.56)$	$-0.00942 \pm 0.0183(-0.515)$	$-0.00109 \pm 0.0188(-0.0579)$	$0.0108 \pm 0.0188(0.577)$	$-0.0519 \pm 0.0184(-2.83)$
4	$-0.031 \pm 0.0183(-1.71)$	$0.0268 \pm 0.0181(1.48)$	$-0.00687 \pm 0.0182(-0.378)$	$-0.00106 \pm 0.0187(-0.0568)$	$0.00908 \pm 0.0189(0.481)$
5	$-0.034 \pm 0.0178(-1.96)$	$0.0231 \pm 0.0189(1.22)$	$-0.0169 \pm 0.0183(-0.92)$	$-0.0138 \pm 0.0183(-0.75)$	$9.56e-05 \pm 0.0184(0.00521)$
6	$-0.031 \pm 0.0186(-1.69)$	$0.0184 \pm 0.0183(1)$	$-0.000709 \pm 0.0182(-0.039)$	$-0.00728 \pm 0.0189(-0.386)$	$0.0223 \pm 0.0182(1.22)$
7	$0.0042 \pm 0.0188(0.22)$	$0.022 \pm 0.0181(1.22)$	$-0.00412 \pm 0.0188(-0.22)$	$0.0044 \pm 0.0187(0.236)$	$0.0291 \pm 0.0188(1.55)$
8	$0.0061 \pm 0.018(0.34)$	$0.0118 \pm 0.0184(0.643)$	$-0.0169 \pm 0.0185(-0.915)$	$0.0244 \pm 0.0182(1.34)$	$0.00532 \pm 0.0188(0.283)$
9	$0.0056 \pm 0.0184(0.30)$	$-0.00938 \pm 0.0182(-0.514)$	$-0.0405 \pm 0.0182(-2.22)$	$0.00885 \pm 0.0182(0.487)$	$0.0361 \pm 0.0185(1.96)$
10	$-0.0156 \pm 0.0185(-0.84)$	$-0.00611 \pm 0.018(-0.34)$	$-0.0241 \pm 0.0184(-1.31)$	$0.0204 \pm 0.0186(1.09)$	$-0.00378 \pm 0.0189(-0.201)$
11	$-0.0079 \pm 0.018(-0.44)$	$0.0539 \pm 0.0182(2.96)$	$-0.0063 \pm 0.0189(-0.334)$	$-0.0297 \pm 0.019(-1.57)$	$-0.00305 \pm 0.0183(-0.166)$

Q^2	S_7	S_8	S_9
0	$-0.0179 \pm 0.018(-0.997)$	$-0.0311 \pm 0.0187(-1.66)$	$0.0274 \pm 0.0184(1.49)$
1	$-0.0221 \pm 0.0183(-1.21)$	$-0.0592 \pm 0.0185(-3.2)$	$0.0151 \pm 0.0181(0.836)$
2	$-0.00449 \pm 0.0185(-0.243)$	$-0.00996 \pm 0.0188(-0.529)$	$0.00609 \pm 0.0186(0.328)$
3	$0.0274 \pm 0.0177(1.55)$	$-0.00217 \pm 0.0186(-0.117)$	$-0.00915 \pm 0.0187(-0.49)$
4	$0.0156 \pm 0.0181(0.861)$	$-0.0141 \pm 0.0186(-0.759)$	$0.00498 \pm 0.0178(0.279)$
5	$0.0158 \pm 0.0186(0.848)$	$0.00727 \pm 0.0191(0.381)$	$0.029 \pm 0.0185(1.57)$
6	$-0.00232 \pm 0.0186(-0.125)$	$0.00974 \pm 0.0177(0.551)$	$-0.00613 \pm 0.018(-0.341)$
7	$-0.00853 \pm 0.0184(-0.463)$	$-0.00649 \pm 0.0182(-0.356)$	$0.00402 \pm 0.0183(0.22)$
8	$-0.0137 \pm 0.0185(-0.739)$	$-0.0167 \pm 0.0185(-0.903)$	$-0.0278 \pm 0.0183(-1.52)$
9	$-0.0229 \pm 0.019(-1.2)$	$-0.0506 \pm 0.0183(-2.77)$	$-0.0269 \pm 0.0183(-1.46)$
10	$-0.0155 \pm 0.0185(-0.84)$	$0.0276 \pm 0.0184(1.5)$	$0.0137 \pm 0.0185(0.742)$
11	$-0.0503 \pm 0.0183(-2.75)$	$-0.0137 \pm 0.0181(-0.758)$	$0.0169 \pm 0.0187(0.902)$

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MM results $1 GeV$ binning, Sigma bias

Q^2	F_l	S_3	S_4	S_5	S_6
0	$0.969 \pm 0.014(2.24)$	$0.979 \pm 0.0142(1.45)$	$0.958 \pm 0.0136(3.11)$	$0.969 \pm 0.0139(2.21)$	$0.975 \pm 0.014(1.8)$
1	$0.998 \pm 0.0154(0.128)$	$0.99 \pm 0.0141(0.684)$	$0.982 \pm 0.014(1.31)$	$1 \pm 0.0142(-0.327)$	$0.988 \pm 0.0152(0.812)$
2	$0.957 \pm 0.0134(3.23)$	$0.989 \pm 0.0142(0.807)$	$0.96 \pm 0.0142(2.79)$	$0.965 \pm 0.0135(2.6)$	$0.973 \pm 0.0143(1.9)$
3	$0.971 \pm 0.0139(2.11)$	$0.971 \pm 0.0137(2.1)$	$0.996 \pm 0.0152(0.277)$	$0.995 \pm 0.0142(0.374)$	$0.967 \pm 0.014(2.39)$
4	$0.971 \pm 0.014(2.09)$	$0.965 \pm 0.0138(2.51)$	$0.966 \pm 0.0137(2.46)$	$0.994 \pm 0.0139(0.44)$	$1 \pm 0.0142(0.00431)$
5	$0.947 \pm 0.0136(3.88)$	$1 \pm 0.0138(-0.165)$	$0.967 \pm 0.0138(2.4)$	$0.978 \pm 0.0137(1.63)$	$0.981 \pm 0.0132(1.46)$
6	$0.983 \pm 0.0142(1.19)$	$0.981 \pm 0.0139(1.35)$	$0.967 \pm 0.0134(2.46)$	$1 \pm 0.0145(-0.126)$	$0.969 \pm 0.0134(2.29)$
7	$1 \pm 0.0144(-0.01)$	$0.968 \pm 0.0142(2.26)$	$0.993 \pm 0.0143(0.474)$	$0.989 \pm 0.0136(0.775)$	$0.991 \pm 0.0138(0.671)$
8	$0.956 \pm 0.0133(3.33)$	$0.98 \pm 0.0138(1.43)$	$0.983 \pm 0.0145(1.18)$	$0.966 \pm 0.0136(2.46)$	$0.996 \pm 0.0145(0.309)$
9	$0.959 \pm 0.013(3.14)$	$0.968 \pm 0.0145(2.21)$	$0.954 \pm 0.0128(3.64)$	$0.963 \pm 0.013(2.8)$	$0.985 \pm 0.0142(1.03)$
10	$0.972 \pm 0.0131(2.11)$	$0.955 \pm 0.0131(3.46)$	$0.978 \pm 0.0141(1.59)$	$0.991 \pm 0.014(0.635)$	$1.01 \pm 0.0137(-0.502)$
11	$0.952 \pm 0.014(3.43)$	$0.969 \pm 0.0141(2.22)$	$0.999 \pm 0.0146(0.0445)$	$1 \pm 0.0144(-0.22)$	$0.979 \pm 0.0143(1.45)$

Q^2	S_7	S_8	S_9
0	$0.958 \pm 0.0139(2.98)$	$0.994 \pm 0.0151(0.42)$	$0.972 \pm 0.0145(1.91)$
1	$0.969 \pm 0.0138(2.24)$	$0.98 \pm 0.0145(1.4)$	$0.963 \pm 0.0137(2.74)$
2	$0.983 \pm 0.0145(1.17)$	$0.998 \pm 0.0146(0.147)$	$0.986 \pm 0.0143(0.98)$
3	$0.942 \pm 0.013(4.43)$	$0.987 \pm 0.0132(0.957)$	$0.996 \pm 0.0145(0.295)$
4	$0.965 \pm 0.0137(2.58)$	$0.986 \pm 0.0138(1)$	$0.965 \pm 0.0131(2.24)$
5	$0.979 \pm 0.0135(1.55)$	$0.978 \pm 0.0149(1.46)$	$0.981 \pm 0.0143(1.33)$
6	$0.983 \pm 0.0139(1.22)$	$0.942 \pm 0.013(4.48)$	$0.955 \pm 0.0136(3.33)$
7	$0.979 \pm 0.0129(1.63)$	$0.97 \pm 0.0145(2.06)$	$0.972 \pm 0.0135(2.05)$
8	$0.979 \pm 0.014(1.5)$	$0.985 \pm 0.0139(1.08)$	$0.971 \pm 0.0136(2.13)$
9	$0.995 \pm 0.0139(0.368)$	$0.975 \pm 0.0142(1.73)$	$0.975 \pm 0.0137(1.82)$
10	$0.988 \pm 0.0132(0.907)$	$0.977 \pm 0.0142(1.59)$	$0.978 \pm 0.0142(1.56)$
11	$0.971 \pm 0.0149(1.97)$	$0.968 \pm 0.0142(2.25)$	$0.988 \pm 0.0137(0.886)$

Conclusions:

- MM does not bias the mean!
- There is a trend that it overestimates the errors.
- From all possible things that could go wrong this is the best.

Fit $1 GeV$ binning, Mean bias

Q^2	F_l	S_3	S_4	S_5	S_6
0	$-0.54 \pm 0.02091(-25.82)$	$0.01246 \pm 0.0213(0.585)$	$0.01828 \pm 0.02126(0.8598)$	$0.02513 \pm 0.02078(1.209)$	$0.0646 \pm 0.02081(3.104)$
1	$-0.27 \pm 0.02232(-12.1)$	$0.03261 \pm 0.02401(1.358)$	$0.08175 \pm 0.02376(3.441)$	$-0.1473 \pm 0.0246(-5.987)$	$-0.244 \pm 0.02276(-10.72)$
2	$-0.7574 \pm 0.02208(-34.3)$	$-0.0307 \pm 0.02267(-1.354)$	$-0.07512 \pm 0.02344(-3.204)$	$0.03054 \pm 0.02523(1.21)$	$-0.2317 \pm 0.02327(-9.957)$
3	$-0.7548 \pm 0.02333(-32.35)$	$-0.01416 \pm 0.02193(-0.6458)$	$-0.1786 \pm 0.02354(-7.588)$	$0.2604 \pm 0.02232(11.67)$	$-0.05868 \pm 0.02325(-2.524)$
4	$-0.5667 \pm 0.02163(-26.2)$	$0.0153 \pm 0.02265(0.6756)$	$-0.2313 \pm 0.02105(-10.99)$	$0.4372 \pm 0.02207(19.81)$	$0.03735 \pm 0.02385(1.566)$
5	$-0.4589 \pm 0.02156(-21.29)$	$0.0305 \pm 0.02265(1.347)$	$-0.2186 \pm 0.02141(-10.21)$	$0.5118 \pm 0.02161(23.69)$	$0.1218 \pm 0.02321(5.249)$
6	$-0.3408 \pm 0.02351(-14.5)$	$-0.005133 \pm 0.0235(-0.2184)$	$-0.3205 \pm 0.02116(-15.15)$	$0.628 \pm 0.02207(28.45)$	$0.2972 \pm 0.02256(13.17)$
7	$-0.2309 \pm 0.02362(-9.778)$	$-0.003081 \pm 0.02186(-0.1409)$	$-0.4115 \pm 0.02268(-18.14)$	$0.6794 \pm 0.02274(29.88)$	$0.4305 \pm 0.02204(19.53)$
8	$0.3543 \pm 0.02837(12.49)$	$0.157 \pm 0.02254(6.969)$	$-0.3984 \pm 0.02223(-17.93)$	$0.3877 \pm 0.02171(17.86)$	$0.8208 \pm 0.02474(33.18)$
9	$0.2385 \pm 0.02778(8.586)$	$0.1185 \pm 0.02156(5.499)$	$-0.3564 \pm 0.02171(-16.42)$	$0.3164 \pm 0.02264(13.98)$	$0.7744 \pm 0.02437(31.78)$
10	$0.2395 \pm 0.0273(8.774)$	$0.2025 \pm 0.02106(9.617)$	$-0.3328 \pm 0.02126(-15.66)$	$0.2583 \pm 0.02247(11.5)$	$0.5419 \pm 0.02453(22.09)$
11	$0.139 \pm 0.02676(5.194)$	$0.3433 \pm 0.02149(15.98)$	$-0.3043 \pm 0.02151(-14.15)$	$0.1217 \pm 0.02339(5.205)$	$0.3523 \pm 0.02402(14.67)$

Q^2	S_7	S_8	S_9
0	$-0.03252 \pm 0.02039(-1.595)$	$-0.02852 \pm 0.02148(-1.328)$	$0.03152 \pm 0.0207(1.523)$
1	$-0.01799 \pm 0.02456(-0.7325)$	$-0.03414 \pm 0.02435(-1.402)$	$0.04347 \pm 0.02277(1.909)$
2	$-0.1108 \pm 0.02502(-4.429)$	$-0.007344 \pm 0.02559(-0.287)$	$0.04804 \pm 0.02257(2.129)$
3	$-0.009689 \pm 0.02367(-0.4093)$	$0.03343 \pm 0.0234(1.429)$	$-0.01668 \pm 0.0209(-0.7982)$
4	$-0.03027 \pm 0.02361(-1.282)$	$0.05424 \pm 0.02354(2.304)$	$-0.02207 \pm 0.02167(-1.018)$
5	$-0.07159 \pm 0.02324(-3.08)$	$0.02229 \pm 0.02396(0.9304)$	$-0.03396 \pm 0.02147(-1.582)$
6	$-0.06034 \pm 0.02395(-2.52)$	$0.04234 \pm 0.02284(1.854)$	$-0.01762 \pm 0.02174(-0.8102)$
7	$-0.05002 \pm 0.02386(-2.097)$	$0.03382 \pm 0.02289(1.477)$	$0.009742 \pm 0.02147(0.4538)$
8	$-0.05097 \pm 0.0245(-2.08)$	$-0.02328 \pm 0.02359(-0.9872)$	$-0.03285 \pm 0.023(-1.428)$
9	$-0.03206 \pm 0.02543(-1.261)$	$-0.009805 \pm 0.02334(-0.4201)$	$-0.04927 \pm 0.02272(-2.169)$
10	$-0.02589 \pm 0.02487(-1.041)$	$-0.005148 \pm 0.02376(-0.2166)$	$-0.02395 \pm 0.02422(-0.9889)$
11	$-0.04134 \pm 0.02664(-1.552)$	$-0.03522 \pm 0.02517(-1.399)$	$-0.02359 \pm 0.0246(-0.9592)$

- With agreement with Michel previous studies LINK

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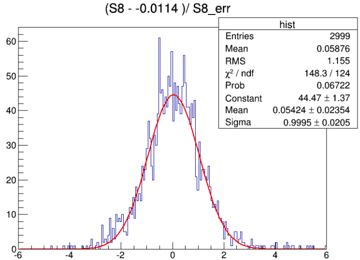
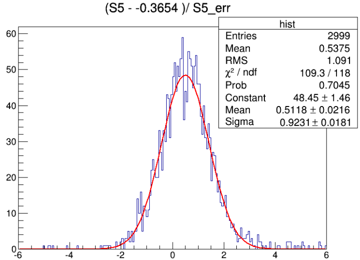
Conclusion on $1GeV$ binning

- Fits Highly bias and not usable.
- MM work fine.
- Christian developed his own fitter
- Let's try comparing those(not very fair comparison)!





MM vs Fit[1]

Q^2	F_l^{MM}	F_l^{Fit}
0	0.0397	0.025
1	0.0802	0.051
2	0.0869	0.057
3	0.0893	0.050
4	0.0878	0.051
5	0.0848	0.048
6	0.0812	0.047
7	0.0775	0.046
8	0.0657	0.041
9	0.0687	0.044
10	0.0755	0.045
11	0.0967	0.061

Q^2	S_3^{MM}	S_3^{Fit}
0	0.0656	0.058
1	0.109	0.100
2	0.116	0.102
3	0.12	0.102
4	0.118	0.101
5	0.115	0.098
6	0.112	0.092
7	0.108	0.087
8	0.0989	0.090
9	0.104	0.098
10	0.114	0.108
11	0.146	0.155

Q^2	S_4^{MM}	S_4^{Fit}
0	0.0639	0.054
1	0.123	0.115
2	0.134	0.114
3	0.137	0.123
4	0.134	0.116
5	0.129	0.112
6	0.123	0.104
7	0.117	0.100
8	0.099	0.086
9	0.103	0.098
10	0.112	0.109
11	0.144	0.160

Q^2	S_5^{MM}	S_5^{Fit}
0	0.0563	0.050
1	0.118	0.114
2	0.131	0.108
3	0.133	0.117
4	0.129	0.105
5	0.122	0.106
6	0.116	0.097
7	0.109	0.094
8	0.0884	0.080
9	0.0925	0.085
10	0.101	0.096
11	0.13	0.144

Q^2	S_6^{MM}	S_6^{Fit}
0	0.0632	0.058
1	0.0936	0.085
2	0.097	0.093
3	0.101	0.085
4	0.101	0.083
5	0.0999	0.085
6	0.0975	0.080
7	0.0941	0.079
8	0.0873	0.073
9	0.0925	0.080
10	0.104	0.100
11	0.137	0.121

Q^2	S_7^{MM}	S_7^{Fit}
0	0.0574	0.051
1	0.118	0.100
2	0.131	0.105
3	0.134	0.111
4	0.131	0.111
5	0.125	0.104
6	0.119	0.102
7	0.113	0.097
8	0.0958	0.085
9	0.101	0.091
10	0.112	0.101
11	0.144	0.136

Q^2	S_8^{MM}	S_8^{Fit}
0	0.0641	0.058
1	0.123	0.113
2	0.134	0.120
3	0.138	0.119
4	0.135	0.112
5	0.13	0.108
6	0.124	0.103
7	0.118	0.101
8	0.104	0.092
9	0.109	0.095
10	0.121	0.115
11	0.156	0.149

Q^2	S_9^{MM}	S_9^{Fit}
0	0.0656	0.057
1	0.109	0.099
2	0.116	0.109
3	0.12	0.104
4	0.119	0.102
5	0.116	0.097
6	0.112	0.094
7	0.108	0.091
8	0.0993	0.079
9	0.105	0.088
10	0.115	0.103
11	0.149	0.143

[1] Taken form Christoph's presentation

Conclusion

- Method of moments a bit worse($\sim 15\%$) then optimistic fit.
- MM overestimates the error by fiew %, fits understimates the error by fiew %.
- Fit needs more study to understand why roofit is biased and Christoph fit is not.